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No. 779.

THE TWENTY-EIGHTH STREET CENTRAL STATION OF THE UNITED ELECTRIC LIGHT AND POWER COMPANY.

By H. W. YORK, Jun. Am. Soc. C. E.

PRESENTED MARCH 18TH, 1896.

WITH DISCUSSION.

The history of the development of the electrical industries for the past few years probably presents the most remarkable example of rapid growth ever recorded, and nowhere is this better exemplified than in the central stations of this and other cities, where the current is generated for distribution over areas of greater or less extent for the supply of light and power. In isolated plants the apparatus is generally small and simple in construction, and the generation of electricity is a matter of secondary importance; the cost of the current generated is comparatively immaterial, and a plant once installed runs until it refuses absolutely to do any more work, when it is sold for junk and another put in its place. In central stations, however, this is not the case. Here the cost of the current generated is a matter of the first importance, and as the growth of business calls constantly for additional capacity, and competition demands constantly better service

and cheaper methods of generation and distribution, in such stations will be found the results of the latest discoveries, inventions and improvements, affecting the entire apparatus required for the generation of current, from the boilers to the switchboard. Here everything is being constantly revolutionized; what was good practice yesterday is obsolete to-day, and what a few years ago was looked upon with wonder and admiration is laughed at to-day as being old-fashioned and out of date.

Boiler-making has been almost entirely revolutionized to meet the requirements of the electrical business; engine-building has undergone changes even more remarkable, but it is in the strictly electrical apparatus that the greatest strides have been made, the other industries simply following in the wake as rapidly as possible and trying to meet the ever-changing conditions. In dynamo-building one of the most noticeable changes to the layman is the increased size of the units. A few years ago a 600-light incandescent dynamo was considered a monstrosity, and when the first were built wiseacres predicted that they could never be made to operate successfully, that they were too big and awkward to handle, and that it was carrying too many eggs in one basket to have 600 lights on one dynamo. To-day a 6 000-light dynamo is considered little more than a baby, while a 600-light machine is scarcely large enough to excite the field of a good-size alternator.

With the increase in the size of the dynamo there has naturally come a reduction in the speed of the armature, making it possible to connect the armature shaft directly to the engine shaft, either by a rigid or a flexible coupling, and to do away with belts, which, under the conditions and at the speeds—seldom less than 6 000 ft. per minute—required in most electrical work are a source of never-ending trouble; this is certainly a long step in the right direction. The author does not wish to incur the enmity of belt men by running down their goods. Belts are very good things and all right in their place, but an electric station is no place for them.

With these changes have come naturally an increased efficiency and various other improvements which, though fully as important as those mentioned, are less noticeable to a person unfamiliar with electrical matters.

The author has been connected for a number of years with the United Electric Light and Power Company, a corporation supplying

electricity for all purposes in the city of New York and formed by the combination of interests of the oldest companies in the field. The stations which the new company acquired and attempted to operate had all been doing service for several years, and the apparatus was naturally somewhat antiquated.

After making numerous changes and improvements, both in the methods of generation and distribution of current, there came a time when alterations would no longer answer the purpose, and the author was instructed to design and erect a new station, to take the place of all the old ones and embody, as far as possible, the best modern practice for the economical generation and distribution of current, as well as the most efficient and reliable service.

The first portion of this station has been erected, and the apparatus has been installed and is in operation, and it is intended to give in this paper a brief description of it as an instance of modern practice in this particular line.

When the subject of a new station was taken up, one of the stations operated by the company was on the south side of East Twenty-ninth Street, the property extending west 280 ft. from the East River and including also eight lots directly in the rear of the station on the north side of East Twenty-eighth Street, but having no water front. This Twenty-eighth Street property was vacant, with the exception of a few small one-story buildings, and was used as a storage yard. This was considered a good central location for the district to be covered, from the Battery to Fifty-ninth Street, and it was decided to design the station to run from street to street, and to erect and equip first the Twenty-eighth Street half, which would have sufficient capacity to take care of the load of all of the present stations, and then to tear down the old station and continue the new one through to Twenty-ninth Street, to provide for future growth of the business. The Twenty-eighth Street half is now erected, and sufficient apparatus has been installed to care for all the load, with the exception of that carried by the old Twenty-ninth Street plant. It is the intention to install during the coming summer the remainder of the machinery in the half already erected, and then remove the Twenty-ninth Street station and complete the new one.

One of the first considerations in laying out work in a large city where property is so valuable as in New York is economy of space, and

in this connection the author considers it worthy of notice that in this station 20 000 H. P. of engines, together with the boilers, pumps, heaters, condensing apparatus, dynamos and switchboard, and storage for 6 000 tons of coal, are all on a plot of ground 160 ft. 11 ins. by 197 ft. 6 ins. All machinery, including the boilers, is on the ground floor, and yet there is plenty of light, air and ample space for working around all the apparatus, both for its ordinary operation and for making repairs.

The building already erected has a frontage of 160 ft. 11 ins., and is a steel frame structure with a brick filling in the walls, except on the north end, which is covered by a corrugated iron curtain wall which will be removed when the Twenty-ninth Street side is built. Figs. 1, 2 and 3 give a general idea of the construction of the building. Fig. 1 is a cross-section of the entire structure, Fig. 2 a longitudinal section through boiler room, and Fig. 3 the roof plan; Fig. 4 shows the front elevation of the building as it appears from Twenty-eighth Street. This entire front wall is hollow and is carried up above the roof, to prevent the noise from the machinery annoying the patients in Bellevue Hospital, which is directly across the street. The wall is really composed of two walls, one 12 ins. thick on the outside, and one 8 ins. thick on the inside, with a 2-in. air space between them. These two walls are bonded together at every sixth course vertically by bricks spaced 20 ins. horizontally, as shown in detail in Fig. 5.

Double windows are also placed on this side of the building, to prevent the noise of the machinery from causing annoyance, and this arrangement has been so successful that, standing directly in front of the building, it is impossible to tell whether or not the machinery is in operation. The foundations for all the machinery rest on solid rock, as do the foundations for the building itself, with the exception of one small corner which has no great weight to carry.

To prevent the transmission of any possible vibration to the adjoining buildings, the foundation walls were kept 1 in. away, and the space filled with sand up to the surface of the ground. Above this point the adjoining walls were covered with tarred paper and the brickwork built against this, thus preventing any possible bond between the brickwork of the station and that of the adjoining buildings. As a matter of fact these precautions were unnecessary as the station walls themselves are absolutely free from any perceptible vibration.

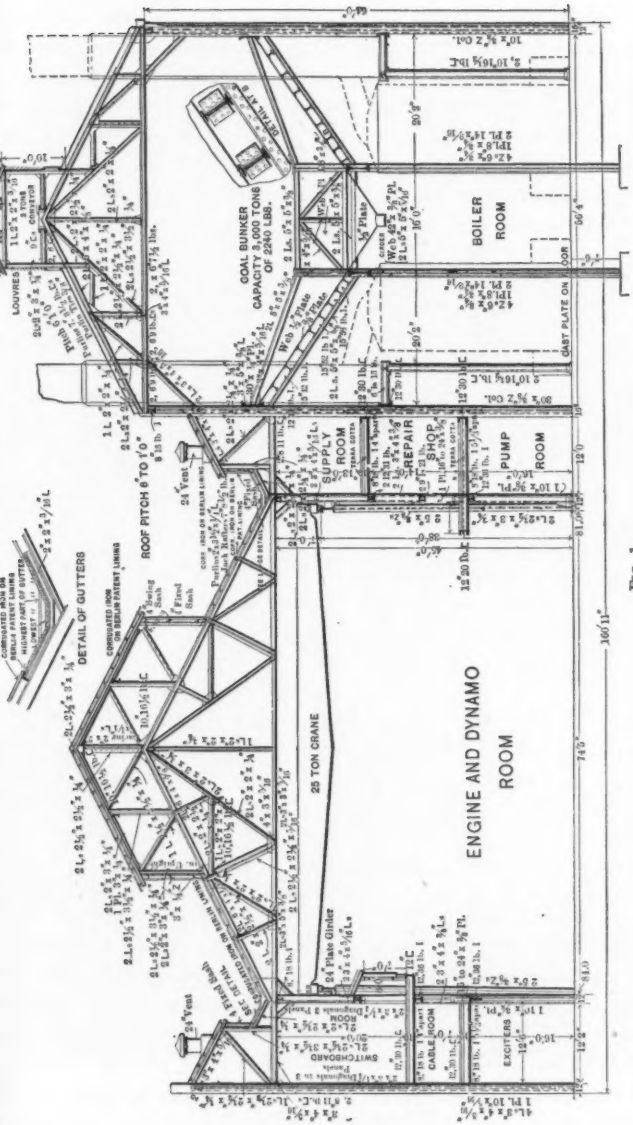
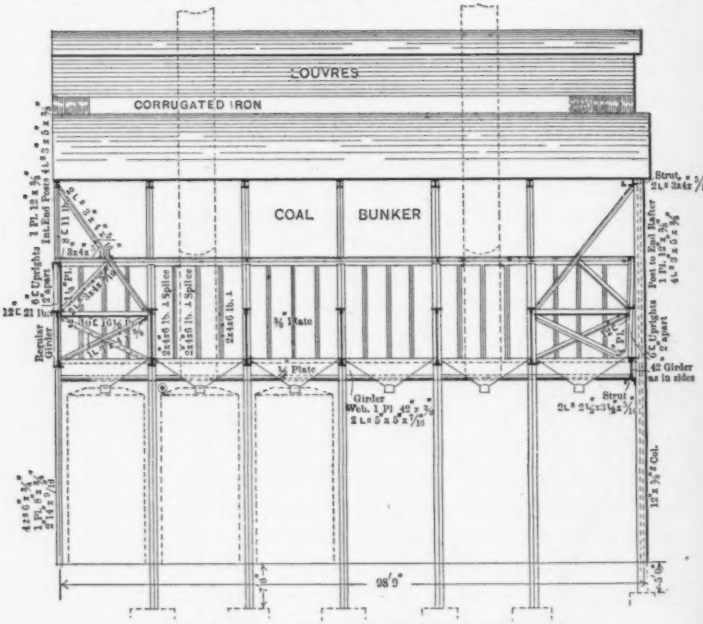

ENGINE AND DYNAMO ROOM
BOILER ROOM
PUMP ROOM
REPAIR SHOP
SUPPLY ROOM
25 TON CRANE
GOAL BUNKER CAPACITY 3,000 TONS OF 2240 LBS.
ROOF PITCH 6 TO 12
DETAIL OF GUTTERS
LOUVRES
SWITCHBOARD ROOM
CABLE ROOM
EXCITERS
160' 11"
74' 0"
66' 4"
80' 0"
12' 0"

FIG. 1.

It was the original intention to excavate down to the rock, which was only a few feet below the surface over the greater part of the area, remove the loose top rock and shale, and build up the foundations as shallow as possible. In the case of the engines it was the intention to build only enough foundation to carry them, and to hold them down by foundation bolts, which were to be secured by rusting in holes drilled in the rock. The rock found, however, was practically useless for the purpose, being full of mica and quite soft, as is



LONGITUDINAL SECTION THROUGH BOILER ROOM
FIG. 2.

most of the rock on Manhattan Island. It became necessary, therefore, to take out enough of this material to allow masonry foundations to be built of sufficient weight to hold the machinery without anchorage. The foundations for the four main engines on each side were built together as one foundation, and are shown in Fig. 6. They are of hard brick, laid in mortar, composed of three parts sand and one of imported Portland cement. Fig. 7 shows a single engine foundation in detail. Fig. 8 is a plan of the foundation walls and piers of

PLATE X.
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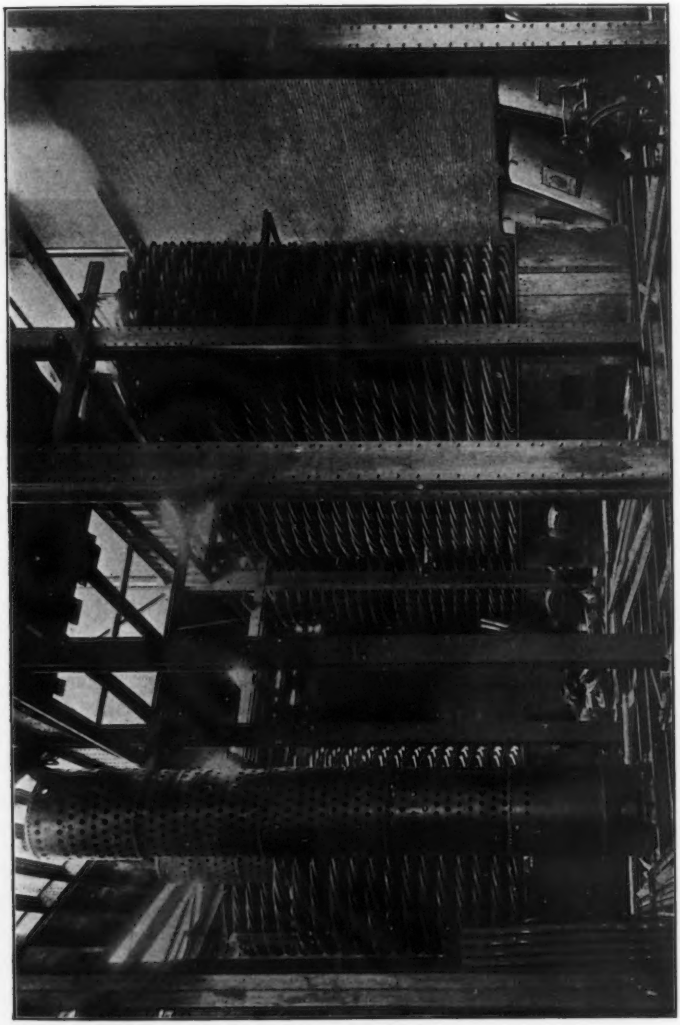

the building, which were constructed in the same manner as the engine foundations.

The masonry was all done by day's work, while the steel frame was let out by contract, as were the piping and all other work of any magnitude.

The boilers are of the upright water-tube type and are in 600 H. P. units. Aside from being economical in the generation of steam, they were selected especially because they occupy so little ground room per unit of capacity. Six are now installed, and six more are required to complete the half of the station now erected. Plate X shows the arrangement of the boilers, as well as their appearance during erection.

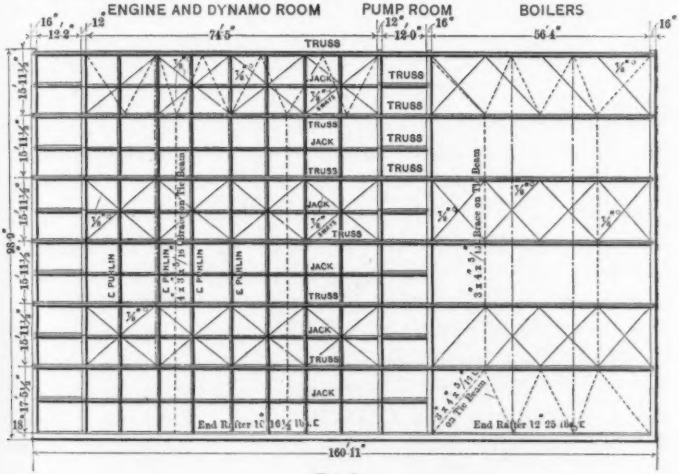

FIG. 3.

It will be seen that part of the boilers have all tubes in place, while the shell of one has just been set up, no tubes having been put in it.

The engine adopted is a Westinghouse double-acting, known as the "Columbian steepled compound," and is of the same type as those used in the lighting station at the World's Fair at Chicago. In fact, three of the engines at present installed were in service in that station. Fig. 9 shows one of these engines in section. The low-pressure cylinder is placed over the high pressure, and both pistons are connected to the same rod. The crank is enclosed in the same manner as is customary in the more familiar types of Westinghouse engines.

The low-pressure valve is operated by a fixed eccentric placed inside the crank case, while the high-pressure valve receives its motion from a shifting eccentric outside the crank case, operated automatically by the governor, which is placed on the shaft outside of the eccentric. The low-pressure valve is of the slide-valve type, while that for the high-pressure cylinder is a hollow piston valve, being constructed in this manner to allow the exhaust from the lower end of the high-pressure cylinder to pass up through it. On account of this construction it is impossible to cushion the valve itself, and this cushioning is accomplished by a plunger, receiving the same motion as the valve, which works in what is termed an inertia cylinder placed outside the crank case, as shown in the cut. This inertia balance is also used for working the engine by hand, the eccentric being first disconnected by throwing over a small hand wheel, and steam being admitted above or below the plunger by means of a small slide valve. The dimensions of these engines are as follows: Diameter high-pressure cylinder, 21½ ins.; diameter low-pressure cylinder, 37 ins.; stroke, 22 ins. The speed is 200 revolutions per minute and the rated horse-power 1 200 when operating condensing, with 150 lbs. initial steam pressure. Plate XI shows the four engines and dynamos already installed on the east side of the engine-room.

Each main engine is directly connected to a 600-kilowatt Westinghouse alternator by a rigid coupling, both engine and generator being set on a firm cast-iron bedplate, as shown in Fig. 7. The generator has but one bearing, the armature being swung between the engine and this single support. Four of these outfits are now erected in place, and four more will be required in the first half of the station. These generators are similar to those used in the lighting station at the World's Fair at Chicago, except that the armatures are wound for a different voltage and are slotted instead of toothed.

By this means the noise, which would be objectionable in a thickly populated district, is almost entirely done away with. The alternators are all arranged to give either single or two-phase current. This is accomplished in two of the four machines already in place by two separate armatures on the same shaft, set at the proper angle in relation to each other to give the form of current required. In the remaining two alternators the same result is accomplished with but a single armature.

PLATE XI.
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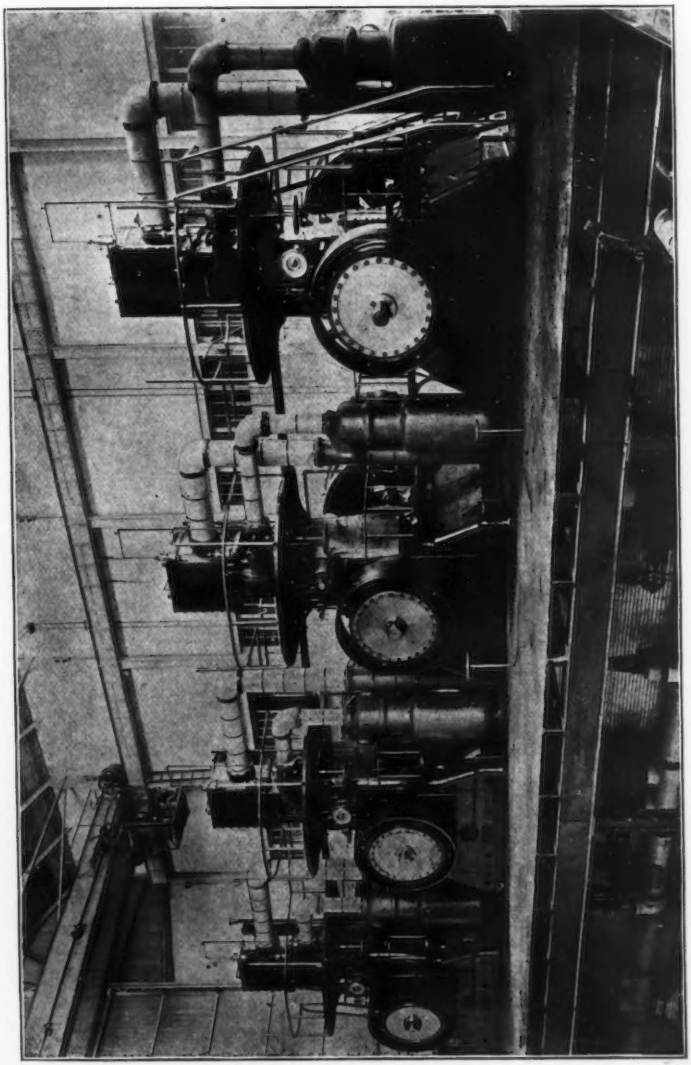

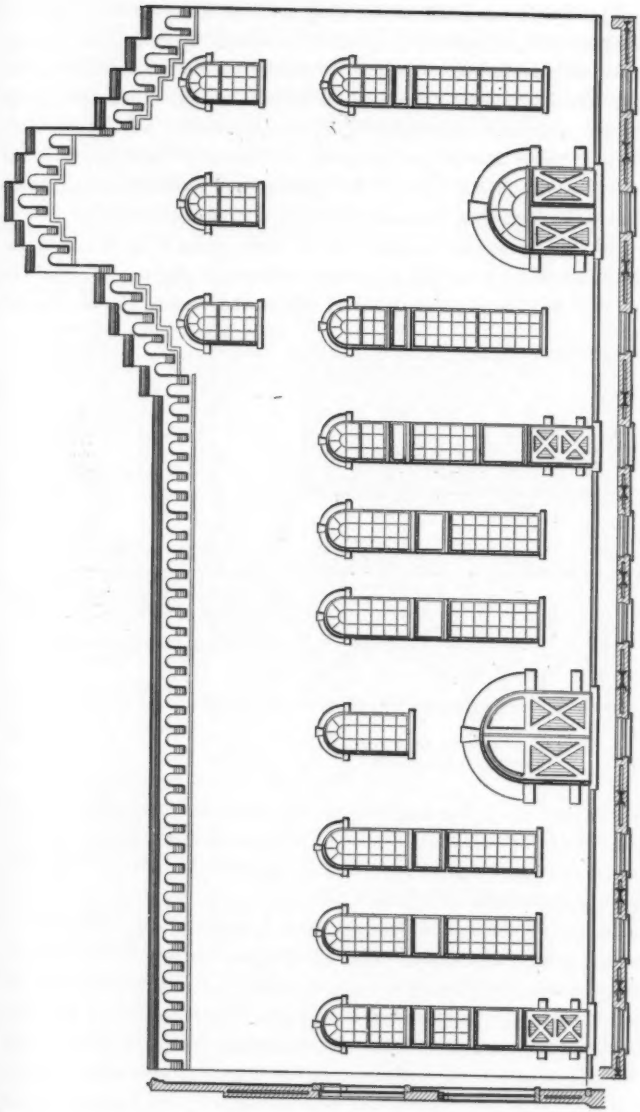

FIG. 4.

For exciting the fields of the alternators 75-kilowatt direct-current Westinghouse dynamos of the railway generator type are used. These are directly connected to 100 H.-P. Westinghouse single-acting tandem compound engines by means of a flexible coupling. Both the engine and the generator are too well known to require any description. Three of these outfits are provided for the eight alternators in the Twenty-eighth Street side of the station, and as each has sufficient capacity to excite four alternators, there is always one spare.

The feed pumps are arranged in the same manner as the exciters; that is, three are provided, any two of which are able to supply all the boilers in the Twenty-eighth Street side of the station at the time of

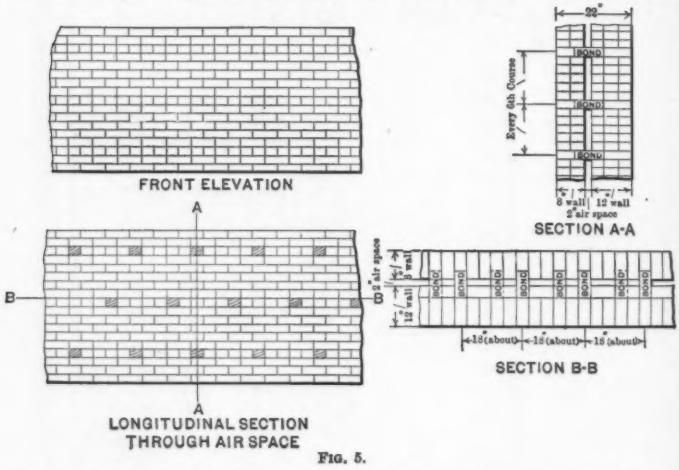

FIG. 5.

the heaviest load, leaving one spare. These are compound duplex pumps 9 and 14 x 8 x 10 ins. The steam supply is controlled by a regulating valve operated by the pressure in the feed mains, so that this pressure is always kept constant.

The entire engine and dynamo-room is spanned by a three-motor electric crane of 25 tons capacity, which is shown in outline in Fig. 1. The span from center to center of the rails is 72 ft. 3½ ins., and the crane itself weighs approximately 45 tons. While a crane of this size and character in a power station may appear to some to be in the nature of an extravagance, the author considers it quite the reverse, and his opinion is borne out in this instance, at least, by the facts, as it has

saved in time and labor more than its cost in setting up the machinery now installed. Moreover, the first cost of the crane is very largely offset by the fact that its presence enabled the roof of the building to be made very light, just heavy enough, in fact, to provide for the wind and snow load, while it would have otherwise been necessary to make every roof truss strong enough to suspend the heaviest part of the engines or dynamos from it, thus materially increasing the cost.

The apparatus for handling coal and ashes is shown in Fig. 10. The

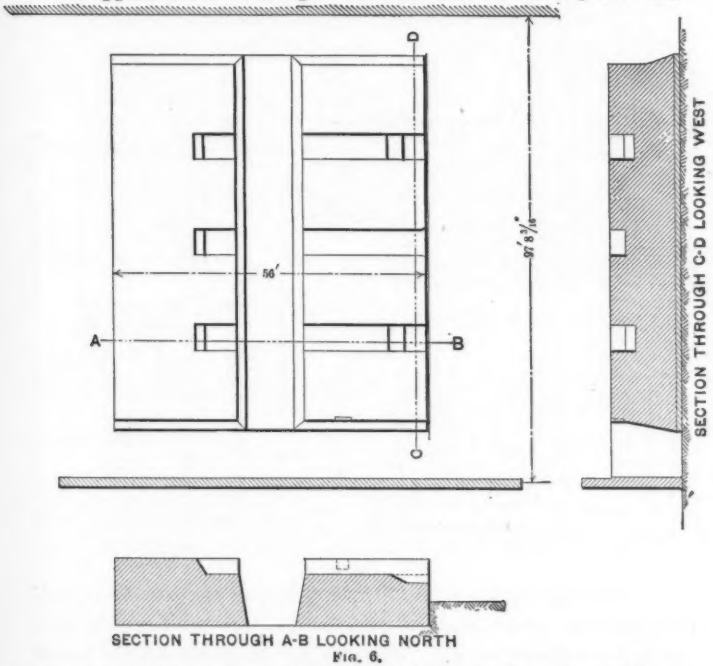

FIG. 6.

conveyor consists of an endless chain of gravity buckets, which are loaded by means of a filler and can be dumped at any desired point. The driver is in the north end of the ventilator over the coal bunker. The coal filler is in a vault under the sidewalk and the coal is dumped into this apparatus through a grating situated at about the street level. After being deposited in the buckets, the coal is carried up into the ventilator over the coal bunker and dumped into any portion of the bunker desired. From the hoppers in the bottom of the bunker,

the coal is spouted to the different boilers. The arrangement is such that the coal trims itself and will continue running down the spouts, as required and without assistance, so long as any remains in the bunker.

When the Twenty-ninth Street side of the station is built, a second conveyor running at right angles to the present one will be put in to bring the coal from the water front. As the company does not own the bulkhead on the Twenty-eighth Street side, however, it is necessary to cart the coal at the present time.

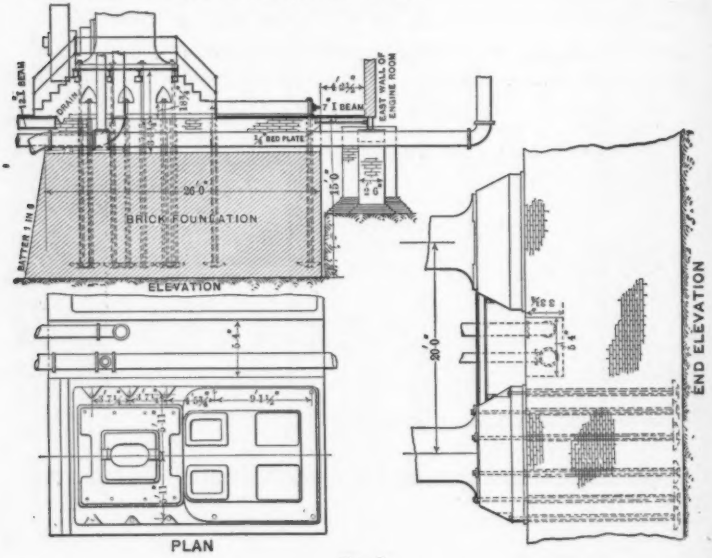

FIG. 7.

Under each boiler is an ash hopper delivering the ashes to a second movable filler, which deposits them in the buckets of the conveyor, when it is not used for coal. The conveyor dumps the ashes at a point from which they are spouted over to a tank in the southeast corner of the coal bunker. From this tank they are spouted down and out through the front of the building into carts. By this arrangement the same conveyor handles both the coal and the ashes, and neither is touched by a shovel, except that for the present the coal is fired by hand. This is a temporary arrangement, however, as the boilers are laid out and set with a view to the use of mechanical stokers, which will probably be applied in the near future.

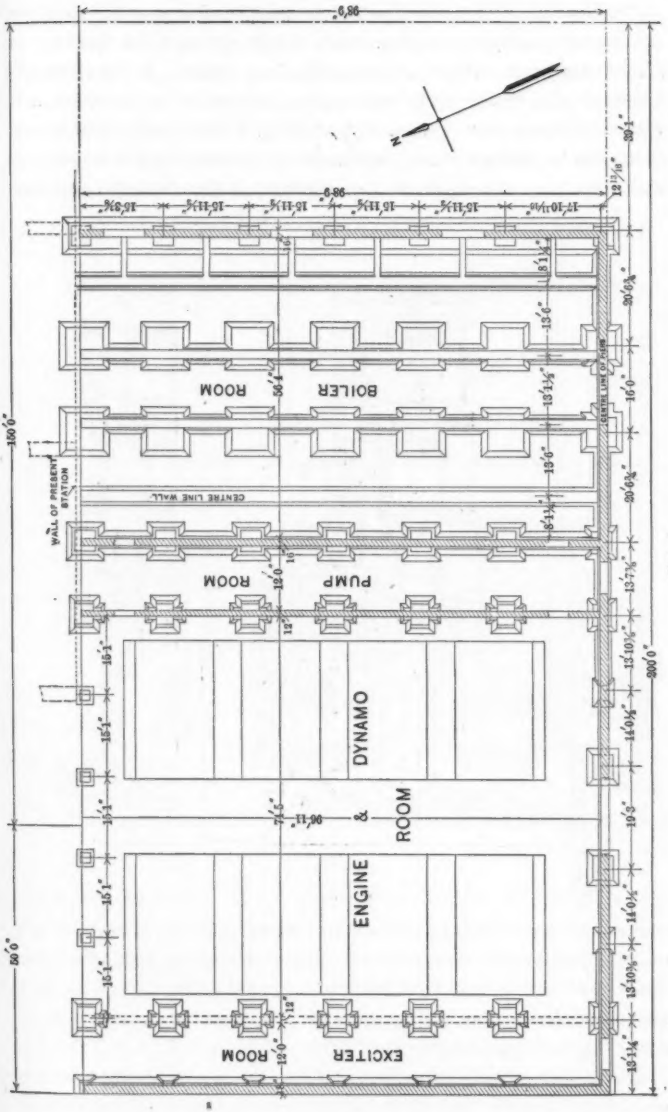

FIG. 8.

END ELEVATION

One feature of this station which is considered of special interest is the arrangement of the piping, which is laid out on what, for want of a better name, the author has termed the loop system. By this arrangement the size of the pipes required is reduced to a minimum, and without going to the expense of providing a duplicate set of pipes, steam can be shut off of any portion of the system without interfering with more than one engine or its equivalent boiler capacity. As this

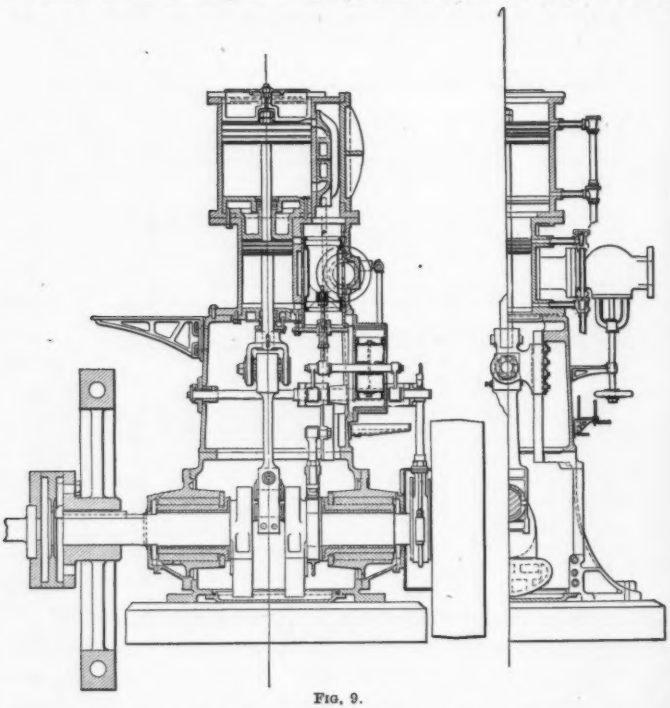

FIG. 9.

amount of spare is always carried, it follows that any portion of the steam-piping system can be cut out without interfering with the operation of the station, and the object of a duplicate set of pipes is thus accomplished without the expense of duplicate pipes and without occupying the space required for them.

The main steam and exhaust piping is shown in plan on Fig. 11 and in elevation on Fig. 12. A 16-in. header is run the length of the boiler-room

and a similar header is run the length of the engine-room between the two rows of foundations, and parallel to the boiler-room header. These are the largest live-steam pipes used and there will be none larger, even when the Twenty-ninth Street side of the station is complete and the entire 20 000 H. P. is installed. Each of these headers is divided into five sections by means of four gate-valves, located as shown, and each section of the boiler-room header is connected to the

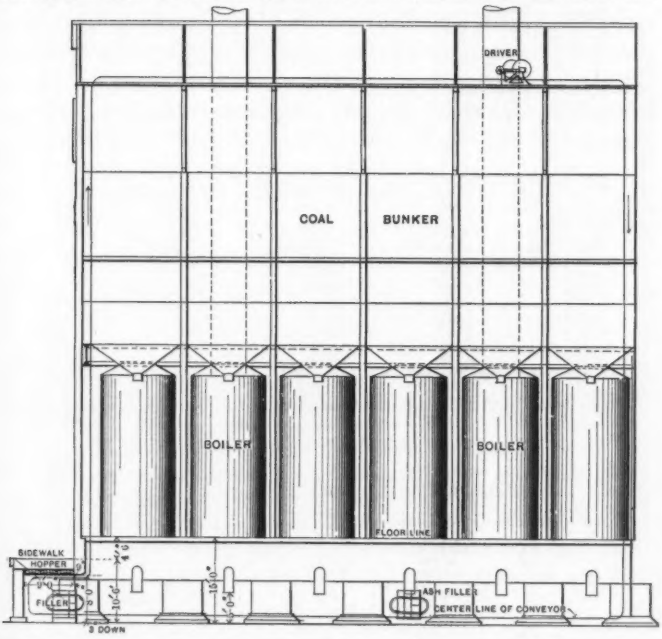

FIG. 10.

corresponding section of the engine-room header by a 14-in. branch rising from the top of one and discharging into the top of the other, a valve being placed on each end where a connection is made to the header. Each boiler has an independent connection to the boiler-room header, supplied with two stop valves, one in the customary position just beyond the safety valves, and the other at the point where the pipe enters the header. This second valve has its stem extended through the wall into the repair shop, so that in case of trouble any

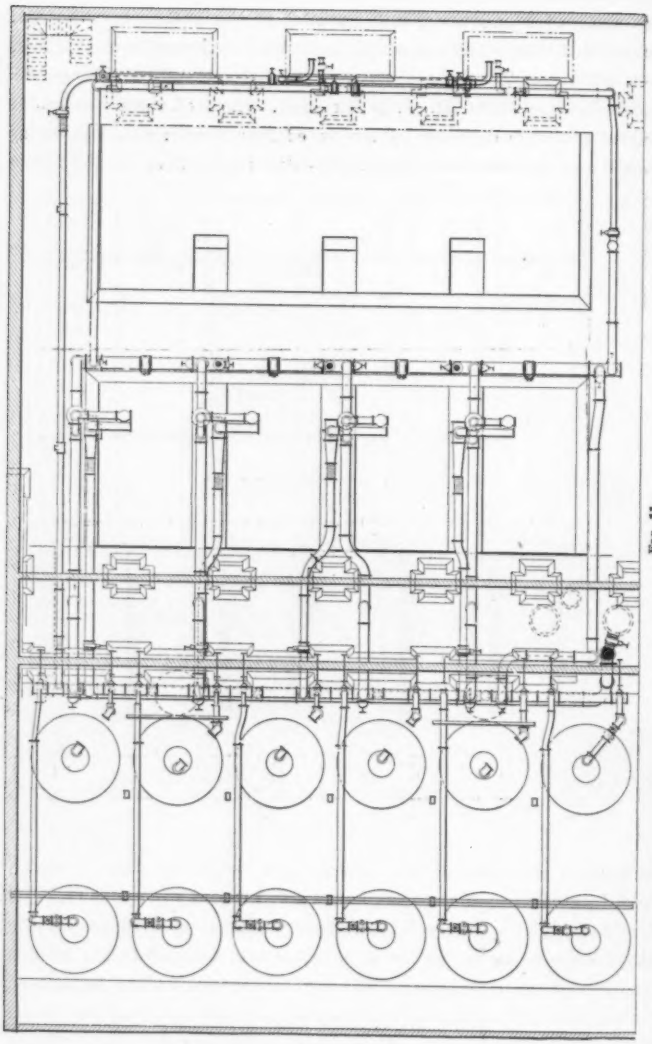

FIG. 11.

boiler may be cut out from a room having no communication with the boiler house.

Each engine on the east side of the engine-room is connected to one of the 14-in. branches previously mentioned, while outlets are left on the engine-room header for connections to the west row of engines as soon as they are placed in position. In case any section of the engine-room header is cut out, one engine connected to this section can be fed directly from the 14-in. branch, leaving only one which cannot be run, and in case any section of the boiler-room header is cut out, no engine need be shut down, as the one connected to the 14-in. branch can be fed back from the engine-room header. One 14-in. branch may at any time be cut out without interfering with the supply of steam, four of these branches being sufficient to furnish ample steam for all requirements.

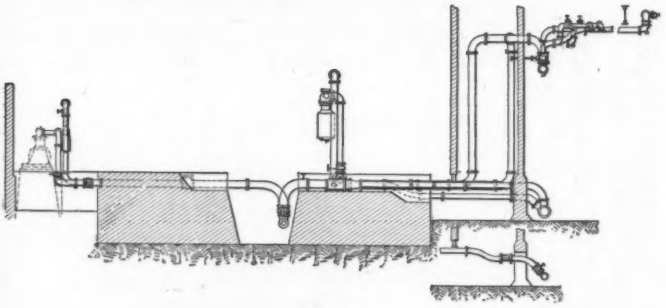

FIG. 12.

The steam pipe for the exciter-engines runs from the north section of the engine-room header around through the exciter-room, and back to the south section of the same header, as shown in Fig. 11. This forms another complete loop, which may be fed from either end in case of trouble with the other, or from both ends in case it becomes necessary to cut out its center.

The steam pipe for the pump-room is arranged in practically the same manner, as shown in Fig. 13, except that in this case the loop is fed not only at the two ends but also at three intermediate points, the same as the engine-room loop.

Another special feature of the steam piping of this station is the use of a combined separator and receiver, shown in detail in Fig. 14, as close to each engine as it is possible to place it. This receiver con-

tains six times the volume of the high-pressure cylinder of the engine, and as the latest cut-off is one-third stroke, it follows that at full load there is at the engine eighteen times the volume of steam required for one stroke. This reservoir prevents the excessive drop in pressure in the pipe when the valve of the engine opens and a corresponding rise above boiler pressure when the valve closes, and keeps a practically uniform flow of steam in the pipe in one direction, allowing the use of smaller pipes than would otherwise be required, and doing away almost entirely with the vibration in the pipes caused by the intermittent flow of steam.

Two low points are provided in the steam piping, from which to take any condensation that may be deposited. One of these is the

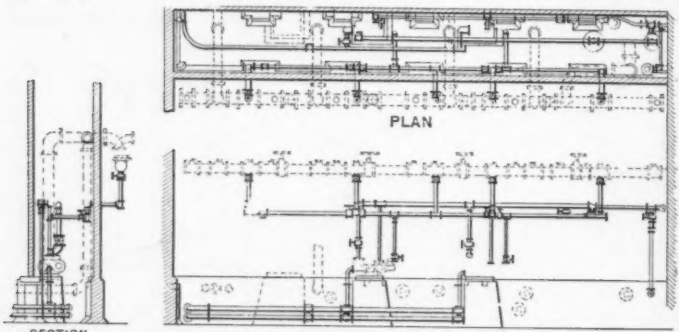

FIG. 13.

pump-room header, and the other a drip main under the engine-room header and connected to each of its sections.

Steam loops from both these points take all condensation and return the water to the boilers. A steam loop is also employed to return the water to the boilers from each of the separators.

Expansion of all live-steam pipes is provided for by long bends and swinging elbows, no expansion joints being used. The boiler-room header is supported by long hangers from the under side of the coal bunker, and is anchored in the middle of its length. The engine-room header is supported in cradles resting on rollers carried on piers, and is free to move horizontally in any direction. The vertical portion of each 14-in. branch connection is provided with a bracket ell at the bottom, which is supported from a pier by means of four 1¼-in. set

screws, so adjusted as to take the weight of the pipe when hot. Hangers are also provided at the upper end of each of these vertical branches, but these carry no strain as long as the pipe is hot. When

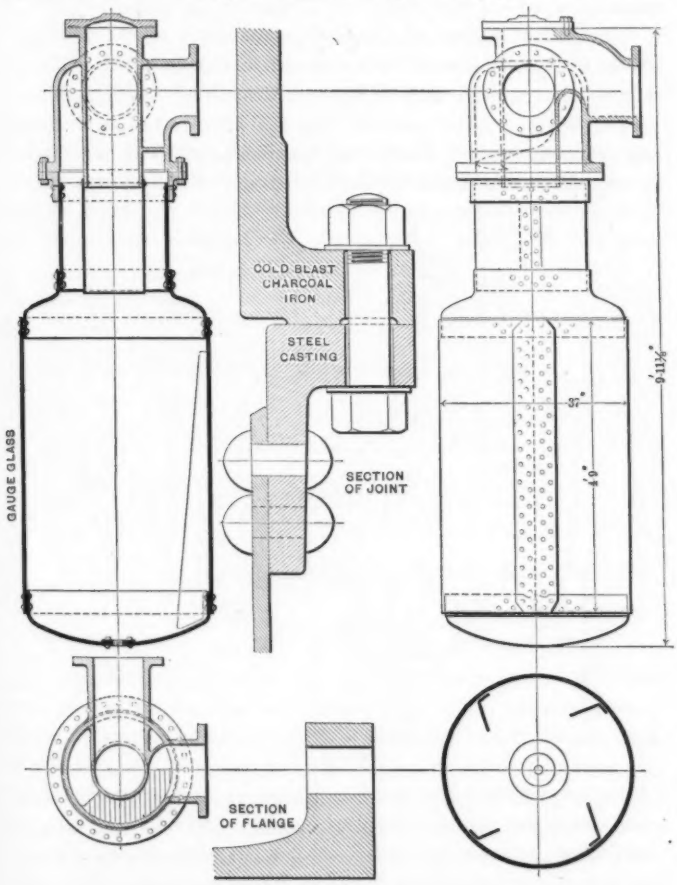

FIG. 14.

steam is shut off and the pipe contracts, the weight is transferred to the hangers, the bottom of the pipe lifting itself clear of the pier. This arrangement is for the purpose of confining the movement to the lower end of the pipe, where provision is made to take care of it.

All pipes, valves and fittings carrying live steam are made extra heavy to provide for 150 lbs. steam pressure, and were tested and made tight under 300 lbs. cold-water pressure after being erected in place.

The exhaust piping contains no special features and is clearly shown in Figs. 11 and 12. A second header will be provided for the west row of engines similar to that for the row already in place, and a third header will be provided, running directly to the condenser and connected to all the engines on both sides. Any engine may then be run either condensing or non-condensing. Fig. 15 shows the de-

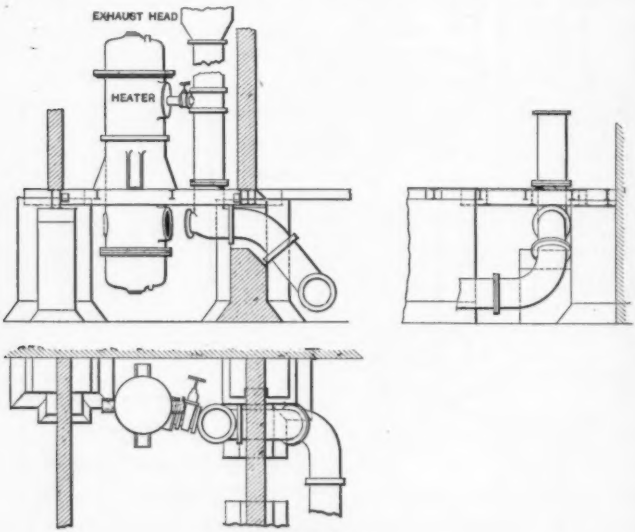

FIG. 15.

tails of the connection of the free exhaust to heater No. 2, and the details of the floor beam system in the north end of the pump room.

Fig. 16 shows the feed and blow-off lines. On the feed lines it will be seen that the loop system has again been employed. The mains make a complete closed loop in the center of the boiler-room, from which the boilers are fed on either side. This loop is fed at either end, the water to reach one end having to pass through the heaters and going directly to the other end. An inspection of the illustration

will show how any section of this system may be cut out without shutting down more than one boiler.

Although provision is made in this station for the switchboard and all the accompanying apparatus, the switchboard room of the old Twenty-ninth Street station has thus far been used, as it is advisable to have both boards in close communication while both stations are running and circuits frequently transferred from one station to the other.

The lead wires from the machines consist of lead-armored cables run in iron ducts directly from each dynamo to its panel on the dynamo board. On this board each alternator as well as each exciter has its own panel equipped with the customary appliances, including

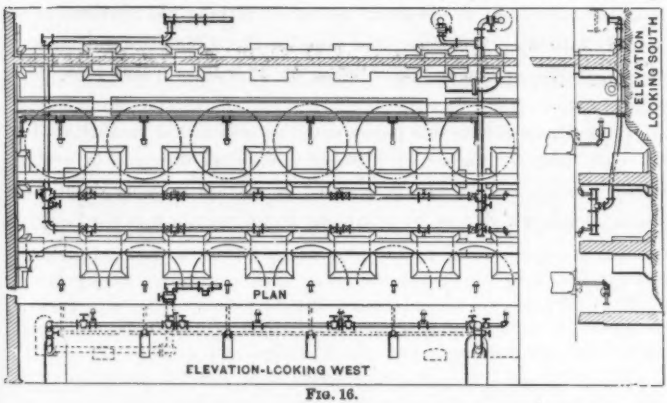

FIG. 16.

volt meter, ammeter, rheostat, fuse blocks, switches, etc. From each panel on this board connection is made to a separate pair of buss bars on the back and running the length of the feeder board, and here each circuit has a separate panel equipped with a volt meter, ammeter, continuous registering meters, etc. At a convenient height on each panel is situated a double-pole dynamo change-switch with the circuit leading out from the center and two flexible cables connected to each end. These cables can be plugged in on any pair of buss bars and a circuit transferred from one dynamo to another by a single throw of the switch. From the center of these switches the circuits run to a third board called the cable terminal board, where, after passing through fuse blocks and a second set of switches used for transferring any

circuit from its own panel to a spare panel provided in case it is desirable at any time to cut any feeder panel dead, connection is made to the ends of the cables, which extend down through the floor and out to the subways. The entire distribution system is underground, and occupies about 150 miles of ducts. The voltage is reduced to any desired pressure by means of converters placed in convenient locations, usually in vaults under the sidewalk. Continuous registering meters are employed to determine the amount of current consumed; they are of the Shallenberger type.

This station has been in constant operation since September 23d, 1895, when it was first started up, and the load on it has been continually growing heavier, as circuit after circuit has been cut over from the old system to the new. So far everything has operated in an entirely satisfactory manner, and none of the difficulties and annoyances usually incident to the starting up of a large plant have been experienced.

The author submits this paper with the belief that in this station are embodied a number of features somewhat unusual in central station design, and he will be pleased to discuss in more detail any special points which may be of interest to the members of the Society.

DISCUSSION.

CHARLES E. EMERY, M. Am. Soc. C. E.—The details of the plant described in the paper show close study. While the larger work of the New York Steam Company was available, so far as the boiler plant is concerned, none of its general features were copied. There are details of steam engineering practice which are common property, but were perhaps never assembled until the steam company's plant was built. The author has combined these details in new and very satisfactory forms, and has employed the precautions which are necessary in case they are used, so that the paper will bear study as to the proper methods of overcoming difficulties in the construction of a plant of this kind. Mr. Emery.

The station of the New York Steam Company was probably the first in which the boilers were placed in tiers, one above the other. This has become the established practice for stations near the central part of a city where land is very expensive, although not to the extent of placing the boilers in four tiers as in the steam company's plant. Water-tube boilers of the Babcock and Wilcox type were installed, and the heating surfaces were undoubtedly as close together as they could be arranged by any plan, although it does not follow that other boilers are not available for central station work. The heating surface of the Morrin boiler used in the plant referred to in the paper is extended vertically to give the power, and a simple smoke pipe can be put on each boiler or a number combined, as in the Twenty-eighth Street station. The steam company's station was built originally to furnish 16 000 H. P. from the entire plant, but that capacity was actually obtained with the boilers on three floors and a few on the fourth, because they were run above their rated capacity. These figures refer to 16 000 H. P. with 30 lbs. of water, while the rating of 30 000 H. P. on the steamship *Lucania* is on the basis of about 15 lbs. of water, so that, on the latter rating, the steam station has a capacity of about 32 000 H. P. and will have more when the fourth tier is filled out. It is therefore the largest single installation of boilers ever made.

The system of steam pipes adopted by the author is practically that used in the distribution of water and gas in cities. It is unnecessary to make the pipe in each street large enough to feed the whole adjoining district. By sending the supply through several pipes, it is possible to feed around a break at any point just as is practiced in the method of electric distribution of the Edison system. The method has been well worked out by the author, and enables any single boiler or engine to be cut out while keeping the pipes small. The loop system of feed pipes is perhaps not so novel. In the construction of the steam

Mr. Emery. company's station, it was considered unnecessary to have the complete duplication of pipes which is now generally adopted, but what is called a donkey system in marine engineering was installed instead. A 6-in. connection was made at the rear of each 250 H. P. boiler, which furnished steam for the pumps and other accessories. By increasing the boiler pressure, steam could be taken through the back pipes and fed to the street mains, as the boilers were of ample strength to carry the additional pressure. This was done on several occasions.

In the electric light stations designed by the engineers of the Edison Electric Illuminating Company of New York City, the speaker recommended for the engines a foundation isolated from the building. This plan had been followed by the president of the company in his house, where the foundation was placed on a bed of sand and did not produce vibrations in the building or in the adjoining houses. Owing to the success of this small plant it was recommended in the uptown stations, with certain features adapted to the locations. The rock was excavated to the necessary depth and covered with a few inches of sand supporting a mass of masonry and concrete to which the engines were bolted. This isolated foundation was nearly the full size of the building, but separated completely from the walls and columns. The aim was to avoid noise more than jarring, and the results were satisfactory, as has also been the case with the author's method of anchoring his engines to the bed rock.

The saving of room in the Twenty-eighth Street station is due in part to the increase in the size of units. In the design of dynamos and electric generators there is great economy due to making them in large units. The generators in this station were regarded with doubt by some engineers before they were tested at the Columbian Exposition by the speaker, as chairman of a committee of the judges in the Department of Electricity, but the test was highly satisfactory, and the engines, notwithstanding their large size, ran regularly at the remarkable speed of 200 revolutions per minute. The steeple form of engine will operate on less floor space than a double engine, but the latter has advantages which will probably cause it to be used more than the single steeple form.

Another improvement adopted in the plant has a marked influence on the economy of electric distribution. It is known that the output through a certain set of conductors is proportioned to the square of the voltage. In this station the generators were wound originally for 2 000 volts, but they were rewound after the close of the Columbian Exposition, and the increased voltage enables the current to be distributed over the entire city without much loss of pressure. The generators in the old station are wound for only 1 000 volts, and give less than one-fourth the amount of electric energy over the same conductors as the new plant. This increase in capacity, due to higher voltage,

may be sufficient in itself to earn dividends, where. perhaps, they could not be obtained under the old conditions. Mr. Emery.

The method of handling coal and ashes in the author's plant, when compared with that in the station of the New York Steam Company, shows the marked improvement in such practice which has been made in recent years. When the latter station was built, the coal conveyor used so successfully in many recent electric light plants had not been brought out. In the steam station coal is dumped into cars at the sidewalk level, the cars are run back, raised by an elevator, run over the coal bins and dumped. The ashes are collected in the basement in similar cars, run to the rear, raised on the elevator and dumped down an ash chute. The system of conveyors in use at the Twenty-eighth Street station is an improvement over this plan, as it is operated with fewer employees.

GEORGE R. HARDY, M. Am. Soc. C. E.—The modern character of the plant described in the paper, as respects boilers, piping, separators, engines, generators and the storage and handling of fuel, and the assured success of such a compact installation on a plot of ground containing 32 000 sq. ft., or 1.6 sq. ft. per horse power, command attention. As a unit for comparison, the engine and its generator may be taken. The 32 000 sq. ft. to be occupied by sixteen such units provides 2 000 sq. ft. for each, inclusive of the proper proportion of space occupied by boilers, exciters and other accessory apparatus. The plan shows that the coal storage area over the boilers measures about 12 000 sq. ft. for a total capacity of 6 000 tons, which is equivalent to a load of half a ton per square foot. This area is usually exceeded in railway coal stations, although in some of the larger stations of 40 000 or 50 000 tons capacity it is about the same. The total horse power represents, after allowing for exciters, 1 200 H. P. for each unit, and is delivered to the generator without any loss of power incident to the use of belting. A comparison of this station with the old plant on Twenty-ninth Street shows that a unit in the new station occupies only 31% as much area as in the old. The speaker doubted if more compactness per horse power could be shown outside of marine engines. Mr. Hardy.

With respect to railways this plant offers suggestive comparisons. Railways are frequently compared with reference to length, but their ratio of equipment is also a matter of much importance. Locomotives demand the first attention. Although they vary widely in efficiency, few roads of large extent are to-day without advanced types of engines combining points of dimensions and usefulness closely approximating the units of the author's station. The newer engines, being more complete, are put in the hardest service, while the older ones are distributed over the lines for the lighter service better fitting their capacity. When the engines are housed the land required measures

Mr. Hardy. about the same for engines as the land per unit at the Twenty-eighth Street Station, not allowing any space for bridges or other structures. An engine-house recently designed, which contains 34 stalls, would require the purchase of a square lot containing 70 756 sq. ft., 2 080 sq. ft. per stall, or about the same area per unit as in the author's central station.

The accompanying table gives a statement of leading data relative to the Columbian steeple compound engine, and three locomotives, viz., the Schenectady consolidation, the New Haven consolidation and the New York Central No. 999 type:

	Columbian.	Schenectady.	New York, New Haven and Hartford.	New York Central.
Weight, pounds.....	200 000	189 100	234 850	204 000
Cylinder, diameter, inches....	21½, 37	21	21	19
" stroke, inches.....	22	26	26	24
Steam pressure, pounds.....	150	170	180	190

The weights are for locomotives and tenders. The heating surface provided for each Columbian engine is 9 000 sq. ft., and that of the Schenectady consolidation locomotive is 2 124 sq. ft.

Railways command such different facilities for securing fuel that no constant supply can be assumed, and even on a single line the provisions vary with circumstances. Some lines near collieries, or located so as to obtain coal conveniently, will carry less than a week's supply, while other lines provide storage capacity for several months' consumption. The coal bins on one road are often furnished with a supply for a year. The electric light station described in the paper, which has water facilities, ought to have a storage capacity for thirty days. This would indicate that the designer anticipated a consumption of 200 tons a day when running the station near its full capacity, thereby averaging 12½ tons per unit daily. If it is conceded that the economy of a plant of this type with compound engines is such that only half as much coal per horse power is used as is consumed and wasted by a locomotive, then each unit will furnish as much power as a locomotive using 25 tons of coal. Locomotives using three tons a day would compare with the station unit as eight to one, which makes the work done at the station under full load equivalent to the work of 128 locomotives.

Some recent tests of consolidation locomotives having 96 000 lbs. on the drivers, and weighing 185 500 lbs. with the tenders, show that 800 H. P. was the greatest amount developed. Where these locomotives worked on heavy adverse grades for 27 miles, with an average resistance of 10 250 lbs., these same tests show that the average horse

power in that distance did not exceed 400, and the down grades on the remainder of the run would probably reduce the work done 50%, making it 200 H. P. The conditions are approximately paralleled in the electric light station where a maximum output, doing most of its work in seven hours, nevertheless averages for 24 hours about 25% of the highest output. Mr. Hardy.

Tests with a 17 x 24-in. passenger locomotive hauling a train weighing about 224 000 lbs. gave the following results:

Speed, miles per hour	50	55	60	65
Boiler pressure, pounds	110	135	125	139
Indicated horse power	229	190	260	350

An electric railway service of thirty 10-ton cars running with frequent stops requires about $16\frac{2}{3}$ H. P. per car. This would indicate apparently that about 670 H. P. is needed for a train of the usual size, but the service of the electric roads has such frequent stops and adverse grades that the same load can probably be moved over a steam road with an expenditure of not over two-thirds this amount.

By means of a diagram showing the position in respect to time of the 134 passenger and freight trains on a certain schedule, it can be shown that in no case are there over 22 trains, $16\frac{2}{3}$% of the total number, on the road at the same time. Assuming that each train requires 440 H. P., the total will be 11 000 H. P., about half the capacity of the electric plant described in the paper. As the allowance of 440 H. P. is somewhat in excess of the actual power as determined by tests, it would seem that half the units of the electric lighting station would furnish sufficient power to operate such a division of standard steam railway, and the station would accordingly have a duplicate set of units for emergencies. If these eight units were located one in every 10 miles they would provide for 128 trains daily on a division 80 miles long, and would consume 100 tons of coal, half the quantity mentioned previously.

E. E. Russell Tratman, M. Am. Soc. C. E.—The author refers to the importance of economizing in space occupied, where land is so valuable as it is in New York, so it would be of interest to know whether any consideration was given to the question of erecting a building for manufacturing or office purposes, which would be a remunerative investment, as well as for power purposes. The location at Twenty-eighth Street, near the East River, is probably not a suitable one for an office building, but may be adapted for certain industries, power for which could be furnished by the electric plant. The plans do not indicate any provision for an extension of this kind. The Metropolitan Traction Company of New York has erected a large office Mr. Tratman.

Mr. Tratman. building over its power plant at Houston Street and Broadway, and the speaker had not noticed any sound or vibration from the machinery in the basement On the other hand, the Third Avenue Railroad Company in the same city has a large one-story power house on the Bowery, which is of somewhat massive appearance, and gives the impression that it is intended to form eventually the lower part of a tall building.

In regard to preventing the transmission of vibration due to the machinery, there have been cases where trouble has occurred from the vibration being transmitted through the foundations and the rock upon which they rest to some considerable distance. This has necessitated the introduction of some form of cushioning in the engine foundations by means of asphalt, timber, etc. In this case no such cushioning seems to have been considered necessary, owing, perhaps, to the easy-running qualities of the engine used.

The nest of closely packed loops of small tubes through which the water circulates in the boilers would seem to make it imperatively necessary to purify the feed water, concerning which the author is silent, since the cleaning and renewing of the tubes and the locating of any defective or leaky tube must be a matter of considerable difficulty. While boilers of this kind are in somewhat extensive use, the speaker had a certain prejudice in favor of a type giving greater accessibility for inspection, cleaning and repairs.

The increasing number of accidents from the bursting of steam main pipes and the serious results of many such accidents led the speaker to inquire what material is used for the steam piping and elbows in this plant, and what provision, apart from the receiver or steam chamber shown in Fig. 14, has been made to ensure against the water hammer which seems to have been considered as the most common cause of the failure of such pipes. The position of stop valves operated from outside the boiler room is a wise precaution, and it is encouraging to read of the careful way in which the piping system has been designed, as this is a detail in steam plants which is too often given but slight attention, and is too often defective in efficiency and safety.

CORRESPONDENCE.

H. W. York, Jun. Am. Soc. C. E.—The question of erecting a building, the upper floors of which could be used for manufacturing purposes, was taken into consideration at the time the station was designed, but there were several reasons which made it appear unadvisable to carry out this construction. On account of the height of the boilers and the space occupied by the coal bunker, the engine-room would be the only portion of the building over which it would be practicable to construct lofts. As this room is 74 ft. 5 ins. between walls, it would be very expensive to provide floors over this space strong enough for manufacturing purposes, unless the girders were supported by intermediate posts, which would interfere with the space in the engine-room and make it impossible to span the entire room with one crane. Again, on account of the advisability of keeping the front of the building closed tight, it was necessary to depend almost entirely for light and ventilation on what could be obtained from overhead, and if this were cut off it would have become necessary to provide mechanical ventilation and use artificial light at all times. Various other questions also entered into the consideration, tending to strengthen the conclusion that it would not be advisable to try to construct a building for anything more than the company's own purposes. Mr. York.

The question of cushioning the engines is one that was studied very carefully, and all the data on this subject which could be obtained were gone over thoroughly. The conclusion reached was that while cushioning between the sides of an engine foundation and the adjacent foundations of a building serves very well to prevent any lateral transmission of the vibration, attempting to cushion under a large engine is apt to increase vibration rather than diminish it, and is also liable to cause serious trouble by allowing the engine to get out of line if the material is not thoroughly confined. In case the danger of throwing the engine out of line is avoided, it then becomes a case of taking up not only the vibration due to the moving parts, but also that due to the entire engine vibrating on the cushion.

While cushioning in some instances may prove effective, the author is decidedly of the opinion that the better method, in most cases, is to provide a foundation heavy enough to take up all shock, and then fasten the engine to this as firmly as possible.

This opinion is certainly borne out by the results in the case in question.

There has been no attempt made in this station to purify the feed water, Croton water being used just as it comes from the mains. While it possibly requires a little more attention to keep a bent-tube

Mr. York. boiler clean than a straight-tube boiler, there is no difficulty, at least where Croton water is used, in keeping them in good shape without taking any extraordinary precautions, such as purifying the feed water. Although the tubes seem to be very closely intertwined they are all easily accessible, and any tube can be readily replaced in a couple of hours.

The steam pipe used in the plant is all full weight lap-welded iron pipe with the exception of the two 16-in. headers, which are built of steel boiler plate. The valves and fittings are all cast iron, but are made extra heavy to provide for the pressure carried.

The provision made to ensure against water hammer is the only provision that can be relied upon to accomplish the purpose, viz., to make it impossible for a quantity of water to collect anywhere in the system. This result is obtained in this station by having all pipes drain in the direction of the flow of steam to low points from which the water is removed as fast as it collects and returned to the boilers by means of steam loops. So thoroughly has this system been carried out that when steam was first put on the cold pipes there was not a sound, not even a snap or a crack anywhere. The author is aware of the fact that steam pipes are often considered to be extremely dangerous, tricky and liable to fill up with water and burst without any provocation, but it has been his experience that, if given half a chance, they are not only safe, but less troublesome than almost any other portion of the apparatus of a power station.